Human Capital Accumulation and Economic Growth*

Mª Jesús Freire-Serén**

Universitat Autònoma de Barcelona
and
Universidade de Vigo

Feb. 1999

WP 435.99

Keywords: Economic growth, human capital accumulation, empirical evidence.

JEL classification: O40, O50.

---

* *I am indebted to Angel de la Fuente, Pablo Antolín, Sonia Llera, Phillipe Polome and Jaime Alonso for their very helpful discussions and comments. Of course, all errors that remain are entirely my own. Financial support from DGICYT grant PB95-130 is gratefully acknowledged.*

** *Mailing address: M. Jesús Freire-Serén, Universidade de Vigo, Facultade de Ciencias Económicas, Lagoas, Marcosende s/n, 36200 Vigo (Pontevedra), Spain. Phone: +34986812524. Fax: +34986812401. E-Mail: mjfreire@uvigo.es.*

Resumen

Presentamos un modelo de crecimiento neoclásico ampliado cuyo proceso de acumulación de capital humano permite analizar la relación entre capital humano y crecimiento económico teniendo en cuenta el efecto de causalidad entre éste y aquel. La estimación llevada a cabo permite obtener tanto los parámetros de la función de producción como aquellos que caracterizan el proceso endógeno de acumular capital humano. La estimación conjunta de las ecuaciones del sistema dinámico revela evidencia a favor de la existencia del llamado efecto nivel de la educación en el crecimiento económico. El resultado cambia cuando se estima únicamente la ecuación de la renta.

Abstract

This paper analyzes the relationship between human capital and economic growth. To that aim, we propose an augmented neoclassical growth model, where the process of human capital accumulation is, in some sense endogenized. The relevance of this modification is that we can analyze how human capital affects growth, considering the reverse impact or causation of growth on human capital accumulation. Thus, we can estimate not only the contribution of human capital to economic growth, but also the effect of income level on human capital accumulation. More precisely, we directly estimate the dynamical system that describes the behavior of the economy. In this way, we obtain the parameters of the aggregate production function and those characterizing the endogenous process of human capital accumulation. Moreover, the joint estimation of the dynamical equations provides evidence about the level effect of education on economic growth. However, when we only estimate the output equation, the outcome changes in the opposite direction.

1. Introduction.

The role of education (or in general, of the formation of human capital) in the growth process has been extensively analyzed in the theoretical literature [see, e.g., Nelson and Phelps (1966), Welch (1970), Lucas (1988), Azariadis and Drazen (1990) and Romer (1990)]. These works identify two ways in which educational investment can contribute to growth. First, human capital can directly participate in the production as a productive factor. In this sense, the accumulation of human capital would generate output growth (the so-called level effect). Second, human capital contributes to raise technical progress since educational formation eases the innovation, diffusion and adoption of new technologies. In this way, the level of human capital affects the productivity growth (the so-called rate effect).

A number of studies have tested the empirical relevance of these theories. The evidence they provide is mixed. While most papers find a positive correlation between educational attainment levels and productivity growth, some cross-country studies find that the coefficient of the educational variable does not enter significatively in a growth accounting regression. Therefore the empirical evidence suggests that human capital contributes to growth through its effect on the rate of technological progress, but there is no clear evidence of the level effect.

The central concern of this paper is to give new empirical conclusions on the relationship between human capital and economic growth. To that aim, we propose an augmented neoclassical growth model, where the process of human capital accumulation is, in some sense, endogenized. The relevance of this modification is that we can analyze not only the contribution of human capital to output growth, but also the effect of the level of income on human capital accumulation. More precisely, we directly estimate the dynamical system that describes the behavior of the economy. In this way, we obtain the parameters of the aggregate production function and those defining the process of human capital accumulation. Furthermore, we also investigate the existence of this level effect estimating the Cobb-Douglas production function. We use both specifications (the dynamical system and the production function) to check if the choice of the specification influences the results about this level effect, as one can conclude from a brief review of some previous empirical contributions to this issue.

Related to this question, Kyriacou (1991) and Benhabib and Spiegel (1994) analyze the relation between human capital and economic growth running the Cobb-Douglas production function in differences where human capital is one of the productive factors. To that purpose, as an index of the human capital stock they use the estimated years of schooling in the labor force, a data set that was constructed by Kyriacou. The results of their studies are surprising, because the estimated coefficients for human capital are not significantly different from zero, and are in some cases even negative. At this point, Benhabib and Spiegel (1994) go one step further considering that technical progress is a function of human capital, and they then estimate different econometric specifications. The results of the later estimations are that human capital coefficients are positive and significantly different from zero. Hence, they only find empirical evidence of the rate effect.

In the present paper, unlike these authors, we express all variables in per worker terms, so that in the estimation of the production function the dependent variables are the accumulated productive factors, i.e., physical and human capital. The human capital indicator that we use is also the estimated years of schooling in the labor force, but we take these data from Barro and Lee (1996), whose quality can be considered superior to Kyriacou's. The first finding in this paper is that the use of output per worker, rather than output per capita, supports the evidence about the positive relation between human capital accumulation and output growth.

On the other hand, the level effect of human capital on economic growth can also be investigated through the convergence analysis proposed by Barro and Sala-i-Martin (1992). In this sense, Mankiw, Romer and Weil (1992) develop an extension of the Solow growth model that incorporates an explicit process of human capital accumulation. In this framework they derive a convergence equation relating the increments of output to the investment rates for both types of capital. This specification allows Mankiw, Romer and Weil (MRW, henceforth) to analyze not only the speed of convergence, but also the direct participation of human capital as an input in the aggregate production. Thus, in the framework of a single cross-country regression, they obtain evidence that confirms the existence of a direct effect of human capital on economic growth. Furthermore, this particular specification allows them to use flow data for both types of capital. In particular, they take the proportion of working-age population that is still studying as a proxy of the investment rate in human capital. Moreover, this use of flow data improves the empirical relevance of the conclusions because their quality is not conditioned to the successive manipulation needed to obtain the stock data.

Islam (1995) considers the work of MRW and examines how the results change with the adoption of the panel data approach. Moreover, he uses a different measure of human capital because the same flow variable as in MRW is not available for a wide cross section of countries. He takes from Barro and Lee (1993) the average schooling years in the total population over age 25 as a proxy of the stock level of human capital. Regarding the role of human capital in the growth process, he finds that it is marginally significant, not only in the panel estimation, but also in the single cross-section regression framework. [1]This result contradicts the one in MRW (1992). One possible reason for this apparent contradiction may be the use of stock data instead of flow data. In any case, the question about the relation between human capital and economic growth still remains unanswered.

The present paper contributes to this open question by identifying the relevant sources of this apparent contradiction about the level effect. From our point of view, one of the main objections to all of these results is that these regressions do not take into account a possible reverse impact of growth on human capital accumulation. A trivial fact is that a larger fraction of the GDP is likely to be invested in education as the economy becomes more developed. In this sense, it is possible to refute the usefulness of the assumption that human capital evolves in the same way as physical capital, i. e., the process of human capital accumulation is a saving function. To that aim, we propose a new interpretation for the process of human capital accumulation. The relevance of this modification is that we can analyze not only the contribution of human capital to growth of output, but also the effect of the level of income on human capital accumulation. More precisely, from our model specification, we build a system of two simultaneous equations representing the dynamic evolution of income and human capital. Our purpose is to estimate this simultaneous system using pooled data. To do that, we will take the same stock human capital index as in Islam (1995), but the revised version of 1996.

This joint estimation of the dynamical equations that describe the behavior of the human capital and the output per worker provides evidence about the level effect of education on economic growth, as MRW's results suggested. However, when we only estimate the output equation, the outcome changes in the opposite direction, being our conclusions about the significance of the human capital coefficient being similar to Islam's. Finally, concerning convergence, unlike Islam´s conclusion, the model predicts a rate of convergence that is similar to the traditional value, also obtained by MRW.

The outline of the paper is as follows. In Section 2, we present the theoretical model from which we derive the econometric specifications used in the empirical analysis. Section 3 details the different sources of data, and it presents the empirical results. Finally, a summary and some concluding remarks are presented in Section 4.

[1]In the same line, Gorostiaga (1999) uses Spanish regional data to estimate, by a panel approach and the instrumental variable technique, a convergence equation based on this framework. She finds that the estimated coefficient of human capital is negative and significant.

2. The Growth Model.

This section presents the benchmark model which is closely related to the one proposed by MRW (1992) although we incorporate a different process of human capital accumulation. We consider a standard economy where the aggregate production function is represented by Cobb-Douglas technology with constant return to scale. More precisely, in each period t the production is given by

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}, \qquad [1]$$

where Y_t is aggregate output, K_t is the stock of physical capital, H_t is the stock of human capital, A_t is a technical efficiency index and L_t is labor. We assume that L_t and A_t grow at constant and exogenous rates n and g, respectively, i.e.,

$$L_t = L_0 e^{nt},$$

$$A_t = A_0 e^{gt}. \qquad [2]$$

Output may be either used for consumption or investment in physical capital. Therefore, the law of motion for physical capital stock is determined by the constant rate of investment in physical capital, s_k, and the depreciation rate of physical capital, δ:

$$\dot{K}_t = s_k Y_t - \delta K_t. \qquad [3]$$

In our economy individuals also accumulate human capital through their schooling formation. This process must not be interpreted in the same way as the law of motion for physical capital stock. While physical capital accumulation is an investment decision of each individual, human capital is accumulated by spending time in schooling without any direct income investment. However, the success of the previous process directly depends on the actual aggregate output, because it determines the productivity of the educational system (infrastructures, R&D, etc. ...) and the willingness of individuals to increase their educational level. For this reason, we consider that human capital has a very different accumulation process than physical capital. Therefore, denoting by $\tilde{Y}_t = Y_t / L_t$ and $\tilde{H}_t = H_t / L_t$, the per worker stock of human capital evolves as follows:

$$\dot{\tilde{H}}_t = \gamma \tilde{Y}_t - (\eta + n)\tilde{H}_t. \qquad [4]$$

Equation [4] says that the growth of human capital per worker depends on the level of output per worker and the actual level of human capital per worker. The decision of accumulating human capital has two components: investment and consumption. Hence, parameter γ, that tries to sum up both components, does not tell us how much income individuals spend on accumulating human capital. It solely shows how the economy translates the achieved income level into an increase in the schooling years achieved labour force. This process must then be interpreted as a consumption function of the total economy, where parameter γ is a kind of "elasticity of human capital accumulation with respect to aggregate income." On the other hand, we must note that the accumulation of human capital also depends on the average level of human capital of the economy. We see above that individuals with higher income give more importance to education than poorer people, so that they are willing to accumulate a larger amount of human capital. In the same line, more educated individuals accumulate more human capital. Parameter η takes into account this positive externality of human capital on the education decision. Parameter η also represents the rate of depreciation and retirement. The sign of this parameter tells us whether the positive externality effect is either larger or smaller than the depreciation effect.

In this model, the economic growth is exclusively driven by labor in efficiency units, which grows at a constant rate $n+g$. For this reason, we can now normalize all variables in efficiency units of labor to characterize the steady-state equilibrium and the dynamics. More precisely, we define the following ratios: $k_t = K_t / A_t L_t$, $h_t = H_t / A_t L_t$ and $y_t = Y_t / A_t L_t$. They represent physical capital, human capital and output per efficiency units of labor respectively. Then, the dynamic equations of the normalized variables are defined by

$$\dot{k}_t = s_k k_t^{\alpha} h_t^{\beta} - (n+g+\delta) k_t, \qquad [3´]$$

$$\dot{h}_t = \gamma k_t^{\alpha} h_t^{\beta} - (n+g+\eta) h_t. \qquad [4´]$$

Expressions [3´] and [4´] characterize the complete dynamics of the economy. We prove in Appendix A that this dynamic system is stable. Hence, given any initial stock of both types of capitals, the variables k_t and h_t converge to their steady-state values. Therefore, computing the steady-state values of k and h by making $\dot{k}_t = 0$ and $\dot{h}_t = 0$, we obtain the steady-state value of output in efficiency units of labor as follows:

$$\bar{y} = \left[\left(\frac{\gamma}{(n+g+\eta)} \right)^{\beta} \left(\frac{s_k}{(n+g+\delta)} \right)^{\alpha} \right]^{1/1-\alpha-\beta}. \qquad [5]$$

The long-run level of income is determined by the technological parameters α and β, the exogenous investment rate s_k, the parameters defining human capital accumulation γ and η, the depreciation rate of physical capital δ, and the long-run growth rate $n+g$. Thus, those countries with a larger physical capital investment rate, a larger "propensity" to accumulate human capital and a smaller growth rate of efficiency units of labor will reach a larger steady-state level of output in efficiency units of labor. Note that an identical value of parameters γ and η for all countries is compatible with different short-run schooling rates across them. These differences in schooling rates would derive from differences in the short-run level of income and human capital per worker. However, human capital will not create differences in long-run level of income.

We are also interested in describing the dynamic behavior of output in efficiency units of labor. Accordingly, in Appendix B, we obtain the following log-linear approximation of this path in a neighborhood of the steady state:

$$\dot{q}_t = \alpha\left[-(1-\alpha)(n+g+\delta)+\beta(n+g+\eta)\right](z_t-\bar{z})$$

$$+\beta\left[\alpha(n+g+\delta)-(1-\beta)(n+g+\eta)\right](u_t-\bar{u}), \qquad [8]$$

where $q_t = \ln y_t$, $z_t = \ln k_t$ and $u_t = \ln h_t$.

At this stage, we should be able to use the theoretical model to estimate the relation between output and human capital. Unlike all related papers [see, e.g., Mankiw, Romer and Weil (1992), Litchenberg (1992)], we will not make use of a convergence equation. With this equation we could only obtain the dependence of output on human capital, but not the converse relationship. We need to find some complete system of simultaneous equations defining the evolution of these variables. We derive this dynamic system in Appendix B as follows:

$$\dot{u}_t = (n+g+\eta)(q_t-u_t)+(n+g+\eta)\ln\left(\frac{\gamma}{(n+g+\eta)}\right), \qquad [9a]$$

$$\dot{q}_t = \beta\dot{u}_t+(n+g+\delta)\beta u_t+\alpha(n+g+\delta)\ln\left(\frac{s_k}{(n+g+\delta)}\right)-\left[(1-\alpha)(n+g+\delta)\right]q_t. \qquad [9b]$$

While the system [9] is expressed in efficiency units of labor, only information on per worker units is, however, available. Hence, we must isolate the technical progress. In particular, we substitute the level of technical progress A_0e^{gt} for A_t. Therefore, after a simple manipulation, and considering that $\tilde{y}_t = \ln(Y_t/L_t)$ and $\tilde{h}_t = \ln(H_t/L_t)$, we can write the econometric specification in the following way:

$$\frac{\tilde{h}_{t+\tau}-\tilde{h}_t}{\tau} = g+(n+g+\eta)\left(\tilde{y}_t-\tilde{h}_t\right)+(n+g+\eta)\ln\left(\frac{\gamma}{(n+g+\eta)}\right)+\varepsilon_{ht+\tau}, \qquad [10a]$$

$$\frac{\tilde{y}_{t+\tau}-\tilde{y}_t}{\tau} = \beta\frac{\tilde{h}_{t+\tau}-\tilde{h}_t}{\tau}+\beta(n+g+\delta)\tilde{h}_t-(1-\alpha)(n+g+\delta)\tilde{y}_t$$

$$+\alpha(n+g+\delta)\ln\left(\frac{s_k}{(n+g+\delta)}\right)+g(1-\beta)+(1-\alpha-\beta)(n+g+\delta)\left(\ln(A_0)+gt\right)+\varepsilon_{yt+\tau}. \qquad [10b]$$

This econometric specification permits us not only to obtain the estimated coefficients of α and β, but also the estimated values of γ and η. This is crucial for two reasons. On the one hand, we can simultaneously obtain the double direction in the relationship between output and human capital. On the other hand, the parameters defining the process of human capital accumulation are not observable, so that their values should simultaneously be estimated with the other technological parameters. Regarding the last point, note that parameters γ and η are not quantified in monetary units. They are expressed in stock units since they represent the variation in the per worker level of education induced by per worker income and by per worker level of education of the economy respectively.

Equations [10a] and [10b] constitute a triangular system of simultaneous equations. Since the random perturbations may be correlated, we must use a jointly estimation method to obtain consistent and efficient estimators. We choose the two-stage, non-linear least square method.[2]

3. Data and Estimation Results.

The main concern of this section is to analyze the empirical relationship between output and human capital. Hence, we will estimate the production function coefficients, α and β, and the parameters defining the process of human capital accumulation, γ and η. To that purpose, we will use the econometric model composed of the system of simultaneous equations [10]. However, in order to place our analysis inside the related literature, we first estimate our production function [1] expressed in levels and in differences.

All estimations will be done using pooled data for different samples of countries during the period 1960-1990. This sample period is subdivided into five-year intervals. In this way, we take seven observations for each country when we run the production function expressed in levels, whereas when we estimate the production function expressed in differences, we consider either a single observation for each country, i.e., the difference between the level of variables in 1960 and 1990, and the variation of shorter periods, in particular the growth rates of 1960-65, 1965-70, 1970-75, 1975-80, 1980-85 and 1985-90, thus we use six observations for each country. Regarding the estimation of system [10], we also take six observations since the endogenous variables are expressed in variation rates. The total sample used on the estimations of the Cobb-Douglas specification has 81 countries. Following MRW, this sample is divided into three subsamples to estimate the simultaneous system. That is, NONOIL (72 countries), where we exclude the oil producer countries, INTER (65 countries), where we exclude small countries and those which

[2]See Appendix C for more details about the estimation procedure.

Summer and Heston identify as countries whose real income data are based on extremely little data and OECD which is made up of the 22 OECD countries with a population greater than one million. The number of countries in the subsamples is different from the MRW's because we do not have human capital data available for all countries for the whole period.

About the source of used data, we acquire the figures for income, population, labor force and investment rates from the Summers-Heston (1996) data set. These data are expressed in real terms and are corrected for differences in purchasing power. Concerning the information on the human capital stock, we consider the revised data set constructed by Barro and Lee (1996). The information of human capital that we use is the estimated educational attainment of the population aged 25 and above. In particular, we will take the average years of schooling as an index of the level of human capital achieved by each country. Finally, the figures for physical capital stock were constructed following the same methodology used by Benhabib and Spiegel (1994).[3]

The investment rate, s_k, and the growth rate of the labor force, n, are both computed for each country as the average of their respective annual values, i.e., $s_k = \frac{1}{5}\sum_{t=1}^{5}(I_t / Y_t)$ and $n_t = \frac{1}{5}\ln(L_{t+5}/L_t)$. On the other hand, we assume that the growth rate of technical progress, g is 0.02.

We next present the results obtained from the estimations of the production function and the dynamical system.

Table I shows the results obtained from the several specifications of the Cobb-Douglas production function.

We begin with the production function of our model expressed in levels, where the data are measured in per worker units. More precisely, we estimate a linear equation where the dependent variable is the logarithm of the level of income per worker and the independent variables are the logarithms of the levels of both physical and human capital per worker, i.e.,

$$\tilde{y}_t = \alpha\tilde{k}_t + \beta\tilde{h}_t + (1-\alpha-\beta)\big(\ln(A_0) + gt\big) + \varepsilon_t . \qquad [11]$$

---

[3] In particular, we look at physical capital stock data from twenty-two OECD countries from 1965 to 1990 from the Summers-Heston (1996) data set. With these data, we estimate an aggregate Cobb-Douglas production function. The results obtained were:

$$\log Y = 4.635 + 0.455 * \log K + 0.587 * \log L + 0.195 * \log H + \varepsilon .$$

Using these estimated coefficients, we build the initial stock of the physical capital K_0 according the equation estimated previously. After having obtained these estimated values for each country, and assuming a rate of depreciation equal to 0.05, we compute the stocks for the all periods through the following equation:

$$K_t = K_0(1-\delta)^t + \sum_{i=0}^{t-1} I_i(1-\delta)^{t-i} .$$

We choose the ordinary least square method where heteroscedasticity is corrected by using White's (1980) estimator for the variance matrix of the estimators.

The first subtable shows the results obtained from estimations of equation [11] for the total sample of countries. We have two columns of results. The first corresponds to the estimation without including dummies for the different continents, whereas the second reflects the estimation when these dummies are introduced (they distinguish among Latin American, African, Asian and OECD countries). We can observe that the estimated coefficient of the stock of human capital per worker is positive and significant in both regressions. Note that the introduction of dummies improves the fit of the regression. However in both cases the low value of the DW test reveals the possible existence of an autocorrelation problem.

At this stage, we must analyze whether the accumulation of human capital also has a positive effect on the growth rate of output. To that purpose, we estimate the production function expressed in differences, as is usual in the related literature [see, e.g., Kyriacou (1991) and Benhabib and Spiegel (1994)]. We derive this specification from the production function [1], where constant returns to scale were assumed. Thus, we estimate the following equation by the ordinary least square method:

$$\tilde{y}_{t+\tau} - \tilde{y}_t = \alpha\left(\tilde{k}_{t+\tau} - \tilde{k}_t\right) + \beta\left(\tilde{h}_{t+\tau} - \tilde{h}_t\right) + (1-\alpha-\beta)g\tau + \varepsilon_{t+\tau}\,. \qquad [12]$$

Equation [12] shows that the variation of output per worker can be attributed to changes in the stock of both physical and human capital per worker.

The results from the estimation of equation [12] are presented in the second subtable. It has two main columns, the first one gives us the result of the single cross-section, and the second one shows the outcomes when we implement a pooled regression on the basis of the five-year span data. We see that there also exists empirical evidence on the positive and significative effect of human capital in the growth rate of output per worker although the fit of the pooled regression is very low. However, we must include an additional comment. These results cannot be compared with the results of Kyriacou (1991) and Benhabib and Spiegel (1994). Since our model assumes constant returns to scale, we have considered a specification where variables were measured in per worker units. However, those authors estimate the production function expressed in total units. Hence, we must also estimate the production function in differences when constant returns to scale are not assumed to investigate how this assumption affects the results. In other words, we estimate the same specification as Kyriacou (1991) and Benhabib and Spiegel (1994), i.e.,

$$\Delta \ln Y = \Delta \ln A + \alpha\Delta \ln K + \beta\Delta \ln H + \gamma\Delta \ln L + \varepsilon\,. \qquad [13]$$

Equation [13] expresses the variation in output as a function of the variation in all the productive factors, i.e., physical capital, human capital and raw labor. The third subtable shows the results of the estimation of equation [13]. These results show that in two cases the coefficient of human capital is not significantly different from zero, similar to those obtained by Kyriacou (1991) and Benhabib and Spiegel (1994). The differences between these previous results and ours showed in this subtable are due to several reasons. For instance, the sample of both countries and periods is different. Moreover and particularly, the data of human capital comes from different source. Therefore, both results should only be compared in qualitative terms.

In conclusion, we observe in Tables I (especially in the first and second subtables) that human capital plays a significant role in the determination of both the level and the variation of output. Furthermore, we conjecture that the puzzling results obtained by previous papers could depend not only on the data used but also on whether the restriction of constant returns to scale is imposed.[4]

Up to this point, we have only estimated the direct effect of human capital on output. However, if the simultaneous relation between human capital and income exists, the previous estimations are biased. For that reason, in this paper we also want to consider the effect of output on the accumulation of human capital together with the former effect. Thus, we suggest the jointly estimation of the system composed of the equations defining the time-evolution of output and human capital. Therefore, we are interested in obtaining from the system [10] the estimated values of parameters γ and β. The first value gives us the effect of output on human capital accumulation, whereas the second provides us with the effect of human capital on the growth rate of output. Since we want to compare our results with those obtained by MRW(1992) and Islam(1995) from their single convergence equation, we try to keep the country samples similar to those used by them. Thus, as we have noted above, our total sample is subdivided in the following three samples: NONOIL that has 72 countries, INTER made up of 65 countries, and OECD composed of 22 countries.

Table II shows the estimated values of parameters γ and η, which determine the evolution of human capital per worker. These results are obtained from the estimation of the first equation in system [10], i.e.,

$$\frac{\tilde{h}_{t+\tau} - \tilde{h}_t}{\tau} = g + (n + g + \eta)\left(\tilde{y}_t - \tilde{h}_t\right) + (n + g + \eta)\ln\left(\frac{\gamma}{(n + g + \eta)}\right) + \varepsilon_{ht}.$$

[4] Both papers are based on the educational data constructed by Kyriacou. We can affirm that the procedure used by him to construct this data set is less sophisticated than the Barro and Lee's.

We observe that output has a positive and significant effect on the accumulation of human capital when we consider both types of samples. These positive values of γ should be interpreted as follows. Each one thousand dollars of annual income per worker achieved by the economy generates in each period t an increase of 0.0000115 years in the schooling formation of the labor force for the NONOIL sample of countries. Note that γ is neither a rate of investment nor represents how much money the people must invest to accumulate human capital. Parameter η also has a positive value, that is 0.06 for all samples. In terms of the model this result means that the positive externality effect from the stock of human capital is smaller than the depreciation effect.

In both samples, the majority of the countries come from Africa and Asia, where the levels of schooling years are very low. This means that the results of Table II could be conditioned due to the presence of many developing countries. To check that, we have also included dummies to distinguish between countries from the OECD, Africa, Asia, and Latin-America. The estimated values of parameters γ and η hardly change if we do not consider that variable, however we maintain these dummies to control differences of the steady state.

After the estimation of the parameters that determine human capital accumulation, we obtain the value of the technological parameter, α and β. To this end, we estimate the second equation in system [10], i.e.,

$$\frac{\tilde{y}_{t+\tau}-\tilde{y}_t}{\tau}=\beta\frac{\tilde{h}_{t+\tau}-\tilde{h}_t}{\tau}+\beta(n+g+\delta)\tilde{h}_t-(1-\alpha)(n+g+\delta)\tilde{y}_t$$
$$+\alpha(n+g+\delta)\ln\left(\frac{s_k}{(n+g+\delta)}\right)+g(1-\beta)+(1-\alpha-\beta)(n+g+\delta)\big(\ln(A_0)+gt\big)+\varepsilon_{yt}.$$

According our estimation method, we use the predicted value in the regression of the first equation in [10] as an instrumental variable for the variation of human capital. Note that this predicted value is obtained from the estimated values of γ and η given by Table II.

Table III, in its first and second columns, shows the outcomes of the previous regression for three samples. We present estimations with temporal and continental dummies. Moreover, we have checked that the significance of the human capital coefficient does not depend on the presence of dummies, and the estimated coefficients are very similar. The value of β is always positive and significant. This result allows us to conclude that there exists a direct empirical relationship between human capital per worker and economic growth. The magnitudes of human capital coefficients are in general larger than the ones that the seminal paper of MRW obtains in the estimation of a convergence equation. We basically impute these differences to the modifications in the specification of the model. Unlike MRW, we endogenize the process of human capital accumulation. Moreover, this difference in the model requires the use of different proxies for the human capital variable although this difference does not change the result about the significance of the human capital coefficient, as one could think after reading Islam's paper.[5] Another possible explanation for the differences between our estimation results and MRW's could be the different size of the subsamples and the period of time considered. Moreover, as Islam (1995) states, the use of our pooled data instead of a single cross section, as MRW consider, can also explain the change in the regression outcomes. Finally, our results are contrary to those given by Islam (1995). Undoubtedly, this is due to the estimation of the simultaneous system that considers the endogeneity of the process of human capital accumulation.

Although we have not developed a convergence analysis, we can still use the previous results to approximate the speed of convergence of the economy to the steady state. We must first calculate the stable eigenvalues λ of the dynamic system [3']-[4'] defining the evolution of the economy. Appendix A describes the analytical expression of these eigenvalues. We now compute their numerical values using the estimation results given in Tables II and III. At this point, we assume for convenience that the speed of convergence is the same for all countries. Thus, we must consider that the value of the growth rate of population, n, is constant across both countries and years. To that purpose, we first take the average value during the period 1960-1990 for each country, and then we calculate the average among countries.

The values of the two stable eigenvalues, which inform us about the conditional convergence, are shown in Table III. These values of λ_1 and λ_2 are not directly comparable with the rate of convergence parameter λ in MRW (1992). They assume that the technologies for the accumulation of physical and human capital are identical, so that their dynamic system defining the evolution of the economy has one dimension. Hence, their speed of convergence is given by a unique eigenvalue. However, since we have assumed different technologies for the accumulation of each type of capital, we have a two-dimensional dynamic system. Thus, the speed of convergence in our model is given by two existing eigenvalues. In order to compare the convergence predictions, we must then compute how much time the economy needs to reach half of the distance from the departure point to the steady state. Denote by H the years that income takes to reach half way to the steady state. These years are implicitly computed in Appendix D as follows:

$$\frac{q_0 - \bar{q}}{2} = c_1 e_{11} \exp\left\{\lambda_1 H\right\} + c_2 e_{21} \exp\left\{\lambda_2 H\right\}. \qquad [14]$$

[5] Remember that MRW use flow data (say, proportion of working-age population that are still studying). whereas we employ stock data (say, average schooling years in the total population over age 25). On the other hand, there are also differences in the size of the samples.

Note that we need to know the initial value of income in efficient units of labor, i.e., q_0. However, the value of A_0 is empirically unknown, so that q_0 cannot be computed. Therefore, in order to compute H we have to assume some initial point q_0. In particular, we take half of the steady state value, i.e., $q_0 = \bar{q}/2$. Moreover, this steady state value is numerically computed using Appendix A and the results presented in Tables II and III. We conclude from the values of H that the speed of convergence in our model, assuming $q_0 = \bar{q}/2$, would be similar to the one estimated in MRW and Barro and Sala (1992), because our calculations give us values between 30 and 36 years.

Before closing this section, we estimate equation [10b] without using the instrumental variable for the variation of human capital. In other words, we directly use the actual series of human capital instead of its predicted value in the previous regression of equation [10a]. Table III shows the results of these estimations in the third and fourth columns. We can observe that the estimated coefficient of human capital is not always significant. This outcome is similar in spirit to that found by Islam (1995) in his pooled regression.

4. Conclusion

This paper has analyzed the empirical relationship between human capital and economic growth across countries. In particular, we have investigated the empirical evidence of the so-called level effect through the simultaneous dependence between human capital and income. To that purpose, we have endogenized the process of human capital accumulation in the augmented neoclassical growth model. Using our theoretical model, we have built a dynamic system describing the simultaneous evolution of income and human capital.

As a first step of our empirical analysis, we have followed the related literature to estimate both the level and the difference specification of the Cobb-Douglas production function. In both specifications, human capital has a positive and significant participation in the production function. Moreover, we conclude that the assumption of constant returns to scale is an important question.

The estimation of the dynamic system of simultaneous equations also confirms that human capital has a positive and significant effect on the growth of income. Moreover, this estimation also concludes that the level of income has a positive and significant effect on the process of human capital accumulation. At this point, we consider that our results are superior to the previous ones based on a convergence equation expressing the growth of income as a function of human capital and other variables. These analyses do not take into account the endogenous dependence of human capital on income. Thus, we have also investigated what happens when endogeneity is not considered. That is, we have only estimated the equation of output, and the result is that the level effect of education on economic growth seems not to be clear.

APPENDIX

A. Stability analysis.

Given the system [3']-[4'] defining the dynamic behaviour of the economy, we compute the steady-values of physical and human capital in efficiency units of labour as

$$\bar{k} = \left[\left(\frac{\gamma}{(n+g+\eta)} \right)^{\beta} \left(\frac{s_k}{(n+g+\delta)} \right)^{1-\beta} \right]^{1/1-\alpha-\beta}, \quad \text{[A1a]}$$

$$\bar{h} = \left[\left(\frac{\gamma}{(n+g+\eta)} \right)^{1-\alpha} \left(\frac{s_k}{(n+g+\delta)} \right)^{\alpha} \right]^{1/1-\alpha-\beta}. \quad \text{[A1b]}$$

Moreover, since $y_t = k_t^{\alpha} h_t^{\beta}$ represents the production function in efficiency units of labour, we obtain from [A1] that the steady-state value of output in efficiency units of labour is

$$\bar{y} = \left[\left(\frac{\gamma}{(n+g+\eta)} \right)^{\beta} \left(\frac{s_k}{(n+g+\delta)} \right)^{\alpha} \right]^{1/1-\alpha-\beta}. \quad \text{[A2]}$$

In order to analyze the behaviour of the economy in a local neighborhood of the steady state, we linearize the dynamic system [3']-[4'] around the steady-state values given by [A1]. Thus, we obtain:

$$\begin{pmatrix} \dot{k}_t \\ \dot{h}_t \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} k_t - \bar{k} \\ h_t - \bar{h} \end{pmatrix}, \quad \text{[A3]}$$

where

$$a_{11} = \left(\frac{\partial \dot{k}_t}{\partial k_t} \right) \Bigg|_{(\bar{k},\bar{h})} = s_k \alpha \bar{k}^{\alpha-1} \bar{h}^{\beta} - (n+g+\delta),$$

$$a_{12} = \left(\frac{\partial \dot{k}_t}{\partial h_t} \right) \Bigg|_{(\bar{k},\bar{h})} = s_k \beta \bar{k}^{\alpha} \bar{h}^{\beta-1},$$

$$a_{21} = \left(\frac{\partial \dot{h}_t}{\partial k_t}\right)\bigg|_{(\bar{k},\bar{h})} = \gamma\alpha \bar{k}^{\alpha-1}\bar{h}^{\beta},$$

$$a_{22} = \left(\frac{\partial \dot{h}_t}{\partial h_t}\right)\bigg|_{(\bar{k},\bar{h})} = \gamma\beta \bar{k}^{\alpha}\bar{h}^{\beta-1} - (n+g+\eta).$$

We prove that determinant and trace of the coefficient matrix in [A3] are positive and negative respectively. It means that both egeinvalues of this matrix are negative. More precisely, these two stable eigenvalues are:

$$\lambda_i = \frac{1}{2}\left(-b^2 \pm (b^2 - 4c)^{1/2}\right), \qquad \text{[A4]}$$

where

$i = 1, 2,$

$b = (1-\alpha)(n+g+\delta) + (1-\beta)(n+g+\eta) > 0,$

$c = (1-\alpha-\beta)(n+g+\delta)(n+g+\eta) > 0.$

Hence, we conclude that dynamic system [3']-[4'] is local stable.

B. The system of simultaneous equations for output and human capital.

To the purpose of this Appendix, we will log-linearly approximate the behaviour of the economy in a local neighborhood of the steady state. Thus, we define $z_t = \ln k_t$, $u_t = \ln h_t$ and $q_t = \ln y_t$. According to [A1] and [A2] the steady-state values of these news variables are respectively

$$\bar{z} = \frac{\beta}{(1-\alpha-\beta)}\ln\left(\frac{\gamma}{(n+g+\eta)}\right) + \frac{1-\beta}{(1-\alpha-\beta)}\ln\left(\frac{s_k}{(n+g+\delta)}\right), \qquad \text{[B1a]}$$

$$\bar{u} = \frac{1-\alpha}{(1-\alpha-\beta)}\ln\left(\frac{\gamma}{(n+g+\eta)}\right) + \frac{\alpha}{(1-\alpha-\beta)}\ln\left(\frac{s_k}{(n+g+\delta)}\right), \qquad \text{[B1b]}$$

$$\bar{q} = \frac{\beta}{(1-\alpha-\beta)}\ln\left(\frac{\gamma}{(n+g+\eta)}\right) + \frac{\alpha}{(1-\alpha-\beta)}\ln\left(\frac{s_k}{(n+g+\delta)}\right). \qquad \text{[B1c]}$$

With this log-transformation, dynamic system [3']-[4'] is rewritten as

$$\dot{z}_t = s_k \exp\{(\alpha-1)z_t + \beta u_t\} - (n+g+\delta), \qquad \text{[B2a]}$$

$$\dot{u}_t = \gamma \exp\{\alpha z_t + (\beta - 1)u_t\} - (n + g + \eta). \tag{B2b}$$

We now linearize the previous system around the steady state [B1]. In this way, we obtain

$$\dot{z}_t = -(1-\alpha)(n+g+\delta)(z_t - \bar{z}) + \beta(n+g+\delta)(u_t - \bar{u}), \tag{B3a}$$

$$\dot{u}_t = \alpha(n+g+\eta)(z_t - \bar{z}) - (1-\beta)(n+g+\eta)(u_t - \bar{u}), \tag{B3b}$$

Moreover, knowing that $\dot{q}_t = \alpha\dot{z}_t + \beta\dot{u}_t$, we obtain from [B3]:

$$\begin{aligned}\dot{q}_t = {} & \alpha\left[-(1-\alpha)(n+g+\delta) + \beta(n+g+\eta)\right](z_t - \bar{z}) \\ & +\beta\left[\alpha(n+g+\delta) - (1-\beta)(n+g+\eta)\right](u_t - \bar{u}).\end{aligned} \tag{B4}$$

At this point, we derive a sytem describing the simultaneous evolution of q_t and u_t by introducing $\alpha(z_t - \bar{z}) = (q_t - \bar{q}) - \beta(u_t - \bar{u})$ into [B3b] and [B4]. Hence, we obtain

$$\dot{u}_t = (n+g+\eta)(q_t - \bar{q}) + (n+g+\eta)(u_t - \bar{u}), \tag{B5a}$$

$$\dot{q}_t = -\left[(1-\alpha)(n+g+\delta) - \beta(n+g+\eta)\right](q_t - \bar{q}) + \beta(\delta+\eta)(u_t - \bar{u}). \tag{B5b}$$

Using steady-state values from [B1], system [B5] can be rewritten as follows:

$$\dot{u}_t = (n+g+\eta)(q_t - u_t) + (n+g+\eta)\ln\left(\frac{\gamma}{(n+g+\eta)}\right), \tag{B6a}$$

$$\begin{aligned}\dot{q}_t = {} & -\left[(1-\alpha)(n+g+\delta) - \beta(n+g+\eta)\right]q_t + \beta(\delta+\eta)u_t \\ & +\alpha(n+g+\delta)\ln\left(\frac{s_k}{(n+g+\delta)}\right) + \beta(n+g+\eta)\ln\left(\frac{\gamma}{(n+g+\eta)}\right).\end{aligned} \tag{B6b}$$

Finally, manipulating [B6b] with [B6a] we obtain

$$\dot{u}_t = (n+g+\eta)(q_t - u_t) + (n+g+\eta)\ln\left(\frac{\gamma}{(n+g+\eta)}\right), \tag{B7a}$$

$$\begin{aligned}\dot{q}_t = {} & \beta\dot{u}_t + (n+g+\delta)\beta u_t \\ & -\left[(1-\alpha)(n+g+\delta)\right]q_t + \alpha(n+g+\delta)\ln\left(\frac{s_k}{(n+g+\delta)}\right).\end{aligned} \tag{B7b}$$

C. Computing the corrected standard errors.

The numerical algorithm used by the MicroTSP to solve a single non-linear equation is different to the one solving non-linear systems. In particular the second procedure is somewhat less sophisticated than the first, as the user´s guide tells us. For this reason, to estimate our simultaneous system [10] we choose the estimation "equation by equation" instead of the estimation of the entire system. That is, we estimate the first equation of the system [10] and then we use these estimated coefficients to compute the instrumental variable for the endogenous regressor of the second equation. However, we must note that the standard errors obtained with the estimation of the second equation are associated to the instrumental variable, while we are interested in the true standard errors corresponding to the observed variable. Therefore, we have to calculate the true standard errors which are different (but they hardly change) from the ones given by the equation by equation estimation procedure.

Hence, for the purposes of this Appendix, we use the following matrix notation to denote the system of simultaneous equations [10]:

$$\psi_t = f(\theta, x_t) + \varepsilon_t , \qquad \text{[C1]}$$

where ψ_t is the (2×1) vector of dependent variables, x_t is the (8×1) vector of explanatory variables and θ is the (5×1) vector of unknown parameters. Since the two-stage least square estimators for systems of non-linear simultaneous equations are a particular case of the Generalized Method of Moments, we use the latter to compute the true standard errors.[6] Let z_{it} denote the vector of instruments that are uncorrelated with the ith element of ε_t. The orthogonality conditions for our econometric model are:

$$g(\theta, w_t) = \begin{bmatrix} [\psi_{1t} - f_1(\theta, x_t) z_{1t}] \\ \cdots \\ [\psi_{1t} - f_1(\theta, x_t) z_{3t}] \\ [\psi_{2t} - f_2(\theta, x_t) z_{4t}] \\ \cdots \\ [\psi_{2t} - f_2(\theta, x_t) z_{8t}] \end{bmatrix}, \qquad \text{[C2]}$$

where $g(\theta, w_t)$ is a (8×1) vector, ψ_{it} and $f_i(\theta, x_t)$ denote ith elements of vectors ψ_t and $f(\theta, x_t)$, and $w_t \equiv (\psi_t', x_t', z_t')'$ respectively. Then, standard errors for $\hat{\theta}$ are calculated considering that

$$\hat{\theta} \approx N(\theta, \hat{V}_T / T), \qquad \text{[C3]}$$

with

$$\hat{V}_T = \left\{ \hat{D}_T \ \hat{S}_T^{-1} \ \hat{D}_T' \right\}^{-1}, \qquad \text{[C4]}$$

where $\hat{S}_T$ is the estimated asymptotic variance matrix, such that

---

[6] See Hamilton (1994, chap 14) for more details.

$$\underset{(8x8)}{\hat{S}_T} = (1/\ T)\sum_{T=1}^{T}[g(\hat{\theta}, w_t)][g(\hat{\theta}, w_t)]' , \qquad [C5]$$

and $\hat{D}'_T$ is calculated by

$$\underset{(8x5)}{\hat{D}'_T} = (1/\ T)\sum_{T=1}^{T} \left.\frac{\partial g(\theta, w_t)}{\partial \theta'}\right|_{\theta=\hat{\theta}} . \qquad [C6]$$

D. Speed of convergence.

In order to compute the speed of convergence as was defined in the main text, we first writte the general solution of the dynamic system [B6]. Stability of this system follows directly from the stability properties obtained in Appendix A for system [3']-[4']. Hence, the general solution of system [B6] is

$$q_t - \bar{q} = c_1 e_{11} \exp\{\lambda_1 t\} + c_2 e_{21} \exp\{\lambda_2 t\} , \qquad [D1a]$$

$$u_t - \bar{u} = c_1 e_{12} \exp\{\lambda_1 t\} + c_2 e_{22} \exp\{\lambda_2 t\} , \qquad [D1b]$$

where c_1 and c_2 are arbitrary constants, λ_1 and λ_2 are eigenvalues [A4], and e_{ij} is j component of eigenvector associated to eigenvalue λ_i. Given initial values q_0 and u_0, we compute from [D1] the constants c_1 and c_2 as follows

$$c_1 = \frac{e_{22}(q_0 - \bar{q}) - e_{21}(u_0 - \bar{u})}{e_{11}e_{22} - e_{12}e_{21}} , \qquad [D2a]$$

$$c_2 = \frac{e_{11}(u_0 - \bar{u}) - e_{12}(q_0 - \bar{q})}{e_{11}e_{22} - e_{12}e_{21}} . \qquad [D2b]$$

We now compute the years that output takes to reach the halfway of the distance from its inital state to its steady-state value. Thus, denoting by H these years, we know that $q_H - \bar{q} = (q_0 - \bar{q})/2$. Therefore, we implicitly obtain H from [D1] as follows:

$$\frac{q_0 - \bar{q}}{2} = c_1 e_{11} \exp\{\lambda_1 H\} + c_2 e_{21} \exp\{\lambda_2 H\} , \qquad [D3]$$

Solving equation [D3], we obtain the value of H. We observe that this value depend on initial value q_0. Hence, we need to assume some departure point. In particular, we consider that $q_0 = \bar{q}/2$.

References

Azariadis, C. and A. Drazen. (1990) "Threshold Externalities in Economic Development," *Quaterly Journal of Economics,* pp. 501-26.

Barro, R. and J-W Lee. (1993) "International Comparisons of Educational Attaiment," *Journal of Monetary Economics,* pp. 363-394.

Barro, R. and X. Sala-i-Martin. (1992) "Convergence" *Journal of Political Economy,* pp. 223-251.

Benhabib, J.and M. Spiegel. (1994) "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data," *Journal of Monetary Economics,* pp. 143-173.

Gorostiaga, A. (1999) "¿Cómo afectan el Capital Público y el Capital Humano al Crecimiento?: Un Análisis para las Regiones Españolas en el Marco Neoclásico," *Investigaciones economicas,* 23.

Hamilton, J. (1994) *Time Serires Analysis*,, Princeton University Press, pp. 409-434.

Islam, N. (1995) "Growth Empirics: A Panel Data Approach," *Quaterly Journal of Economics,*, pp. 1127-70.

Kyriacou, G. (1991) "Level and Grow Effects of Human Capital: a Cross-Country Study of the Convergence Hypothesis," Mimeo, NYU.

Litchemberg, F. (1992) "R&D Investment and International Productivity Differences" NBER Working, Paper nº 4161.

Lucas, R. (1988) "On the Mechanics of Economic Development," *Journal of Monetary Economics,* pp. 3-42.

Mankiw, G., D. Romer and D. Weil. (1992) "A Contribution to the Empirics of Economic Growth," *Quaterly Journal of Economics,* pp. 407-437.

Nelson, R. and E. Phelps. (1966) "Investment in Humans, Technological Diffusion, and Economic Growth," *American Economic Review,* pp. 69-82.

Psacharopoulos, G.and A. Arriagada. (1986) "The Educational Composition of the Labour Force," *International Labour Review*, pp. 561-574.

Romer, P. (1989) "Human Capital and Growth: Theory and evidence," NBER Working, Paper nº 3173.

Summers, R., and A. Heston. (1996) "The Penn World Table (Mark 5.6): An Expanded Set of International Comparisons, 1050-93," *Quaterly Journal of Economics.*

Welch, F. (1970) "Education in Production," *Journal of Economics of Political Economy*, 78, pp. 35-59.

Table I
Estimation of Production Function Especifications

$$\tilde{y}_t = \alpha\tilde{k}_t + \beta\tilde{h}_t + (1-\alpha-\beta)\left(\ln(A_0) + gt\right) + \varepsilon_t \qquad [11]$$

	pooled data	
cte	9.93	10.01
	(0.4184)	(0.3060)
α	0.52	0.39
	(0.0113)	(0.0139)
β	0.04	0.05
	(0.0108)	(0.0098)
Continental dummies	no	yes
R^2	0.81	0.85
N	567	567

$$\tilde{y}_{t+\tau} - \tilde{y}_t = \alpha\left(\tilde{k}_{t+\tau} - \tilde{k}_t\right) + \beta\left(\tilde{h}_{t+\tau} - \tilde{h}_t\right) + cte + \varepsilon_{t+\tau} \qquad [12]$$

	[1]single cross-section	[2] pooled data	
cte	-0.21	0.03	0.05
	(0.0890)	(0.0093)	(0.0193)
α	0.34	0.16	0.18
	(0.0344)	(0.0177)	(0.0276)
β	0.15	0.20	0.13
	(0.0845)	(0.0431)	(0.0436)
Temporal dummies	no	no	yes
R^2	0.58	0.21	0.28
N	81	486	486

$$\Delta \ln Y = \Delta \ln A + \alpha\Delta \ln K + \beta\Delta \ln L + \gamma\Delta \ln H \qquad [13]$$

	[1]single cross-section	[2] pooled data		Kyriacou	Benhabib-Spieguel
cte	-0.04	0.08	0.11	0.009	0.26
	(0.1146)	(0.0134)	(0.0211)	[1.62]	(0.090)
$\Delta \ln K$	0.34	0.15	0.16	0.44	0.45
	(0.0353)	(0.0171)	(0.0277)	[5.05]	(0.085)
$\Delta \ln L$	0.312	0.26	0.28	-0.152	0.063
	(0.117)	(0.0948)	(0.0926)	[-1.68]	(0.079)
$\Delta \ln H$	0.10	0.12	0.05	0.26	0.20
	(0.0914)	(0.0399)	(0.0410)	[0.9]	(0.207)
Temporal dummies	no	no	yes	no	no
R^2	0.60	0.19	0.27	0.47	0.51
N	81	486	486	87	78

Notes:
- Sample period for our estimations is 1960-90. Our sample has 81 countries. Sample period for Kyriacou's estimation is 1970-85 and has 87 countries; for Benhabib & Spieguel's estimation, is 1965-85 and has 78 countries.
- Standard errors are in parenthesis below corresponding coefficients, but Kyriacou's results, where t-test appears in brackets.

Table II.

Estimation of human capital equation in the dynamical system

$$\frac{\tilde{h}_{t+\tau}-\tilde{h}_t}{\tau}=g+(n+g+\eta)\left(\tilde{y}_t-\tilde{h}_t\right)+(n+g+\eta)\ln\left(\frac{\gamma}{(n+g+\eta)}\right)+\varepsilon_{ht+\tau}\,.$$

	NONOIL	
η	0.064	0.064
	(0.0051)	(0.0036)
γ	1.12E-08	1.15E-08
	(1.06E-09)	(4.4E-09)
t.d.	yes	no
c.d.	no	yes

	INTER	
η	0.064	0.064
	(0.006)	(0.006)
γ	4.6E-08	4.99E-09
	(9.1E-10)	(9.13E-10)
t.d.	yes	no
c.d.	no	yes

	OECD
η	0.066
	(0.008)
γ	4.4E-09
	(6.7E-10)
t.d.	yes
c.d.	no

Notes:
-There are six observations for each country. Sample period for estimations is 1960-90. NONOIL sample has a total of 432 observations, INTER sample has a total of 390 observations, and OECD sample has a total of 132 observations.
- t.d. indicates whether estimation includes "temporal dummies."
- c.d. indicates whether estimation includes "continental dummies."
- Standard errors are in parenthesis.

Table III

Estimation of output per worker equation in the dynamical system

$$\frac{\tilde{y}_{t+\tau}-\tilde{y}_t}{\tau} = \beta\frac{\tilde{h}_{t+\tau}-\tilde{h}_t}{\tau} + \beta(n+g+\delta)\tilde{h}_t - (1-\alpha)(n+g+\delta)\tilde{y}_t$$
$$+\alpha(n+g+\delta)\ln\left(\frac{s_k}{(n+g+\delta)}\right) + g(1-\beta) + (1-\alpha-\beta)(n+g+\delta)\left(\ln(A_0)+gt\right)+\varepsilon_{yt+\tau}$$

	with instr.vble.	**with instr.vble.**	**without instr.vble.**	**without instr.vble.**	**MRW.**	**Islam**
			NONOIL			
cte	29	35	8	9.0	2.4	
	(2.3807)	(7.4640)	(0.5476)	(0.5742)	(0.48)	
α	0.38	0.35	0.64	0.58	0.48	0.80
	(0.1553)	(0.0215)	(0.0123)	(0.0199)	(0.07)	(0.053)
β	0.39	0.40	0.01	0.02	0.23	0.05
	(0.0674)	(0.0345)	(0.0118)	(0.0130)	(0.05)	(0.102)
t.d./c.d.	yes/no	no/yes	yes/no	no/yes	no/no	no/no
λ_1 / λ_2	0.022 /0.09	0.024 /0.09			0.014	0.0069
N	432	432	432	432	98	480
			INTER			
cte	38	32	8.3	9.2	3.0	
	(12.613)	(9.9626)	(0.6221)	(0.6664)	(0.53)	
α	0.39	0.43	0.68	0.64	0.44	0.78
	(0.0582)	(0.0544)	(0.0139)	(0.0213)	(0.07)	(0.0058)
β	0.38	0.33	0.02	0.03	0.23	-0.007
	(0.0286)	(0.0298)	(0.0013)	(0.0124)	(0.06)	(0.1288)
t.d./c.d.	yes/no	no/yes	yes/no	no/yes	no/no	no/no
λ_1 / λ_2	0.022 /0.09	0.022 /0.09			0.018	0.0079
N	390	390	390	390	75	370
			OECD			
cte	21		5.7		3.5	
	(25.262)		(0.7976)		(0.63)	
α	0.49		0.70		0.38	0.60
	(0.0582)		(0.0319)		(0.13)	(0.1015)
β	0.21		-0.02.		0.23	0.017
	(0.0562)		(0.0116)		(0.11)	(0.1797)
t.d./c.d.	yes/no		yes/no		no/no	no/no
λ_1 / λ_2	0.025 /0.09				0.020	0.016
N	132		132		22	110

Notes:
- There are six observations for each country, that belong to period 1960-1990.
- Period time considered by MRW and Islam is 1960-1985. Moreover the sample groups do not have the same exactly number of countries.
- t.d./c.d. means whether the estimation includes temporal or continental dummies.
- λ_1 / λ_2 means absolute value of eigenvalues of our system and also means the unique eigenvalue of the convergence equation estimated by MRW and by Islam.
- Standard errors are in parenthesis below corresponding coefficients.